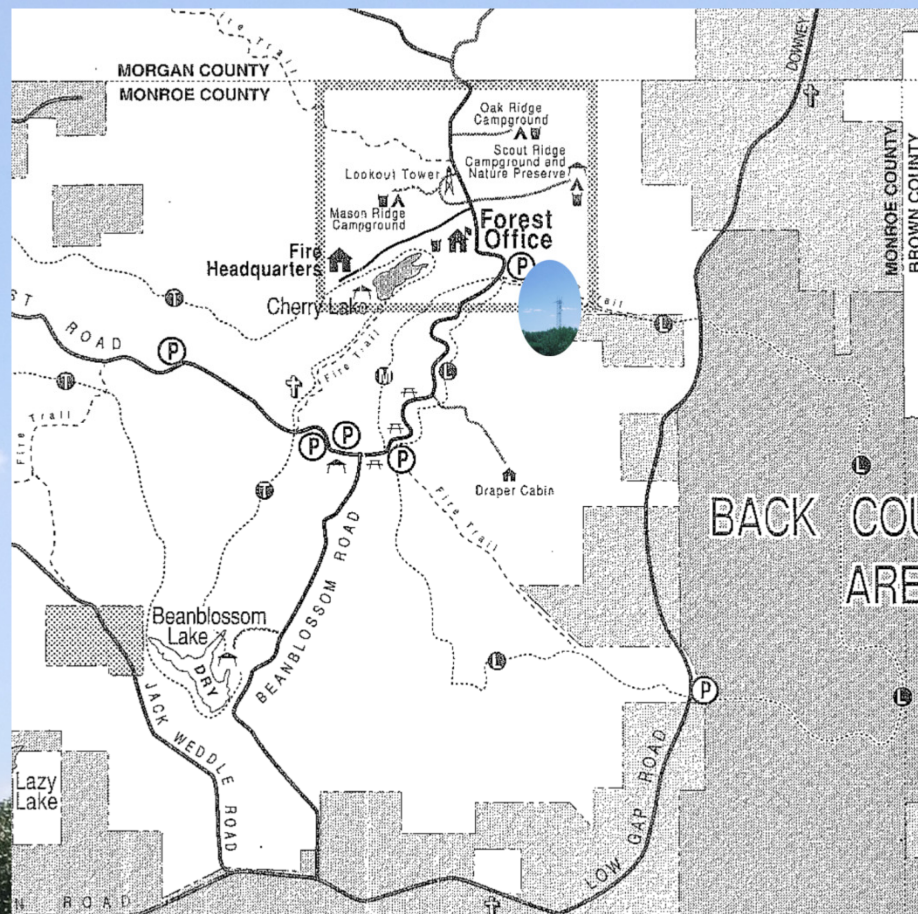
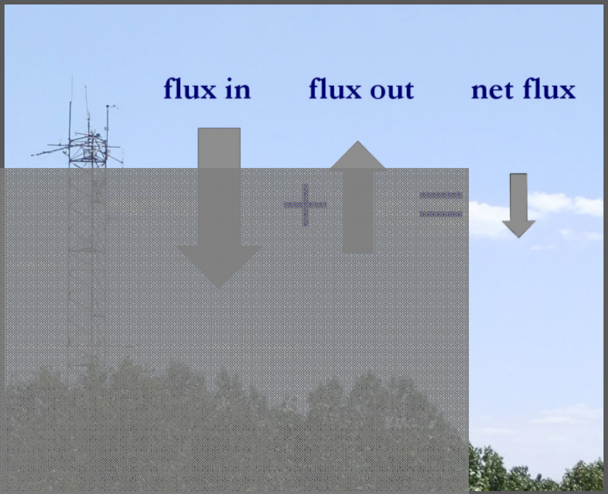
The Morgan-Monroe State Forest flux tower: history, context, and some recent findings



Kim Novick (IU SPEA) & Eddie Brzostek (IU Dept. of Biology)

The Morgan-Monroe Flux Tower:
long-term (15 years and counting) monitoring of forest-atmosphere fluxes of carbon dioxide and water vapor



OUTLINE:

I. Why?

II. How?

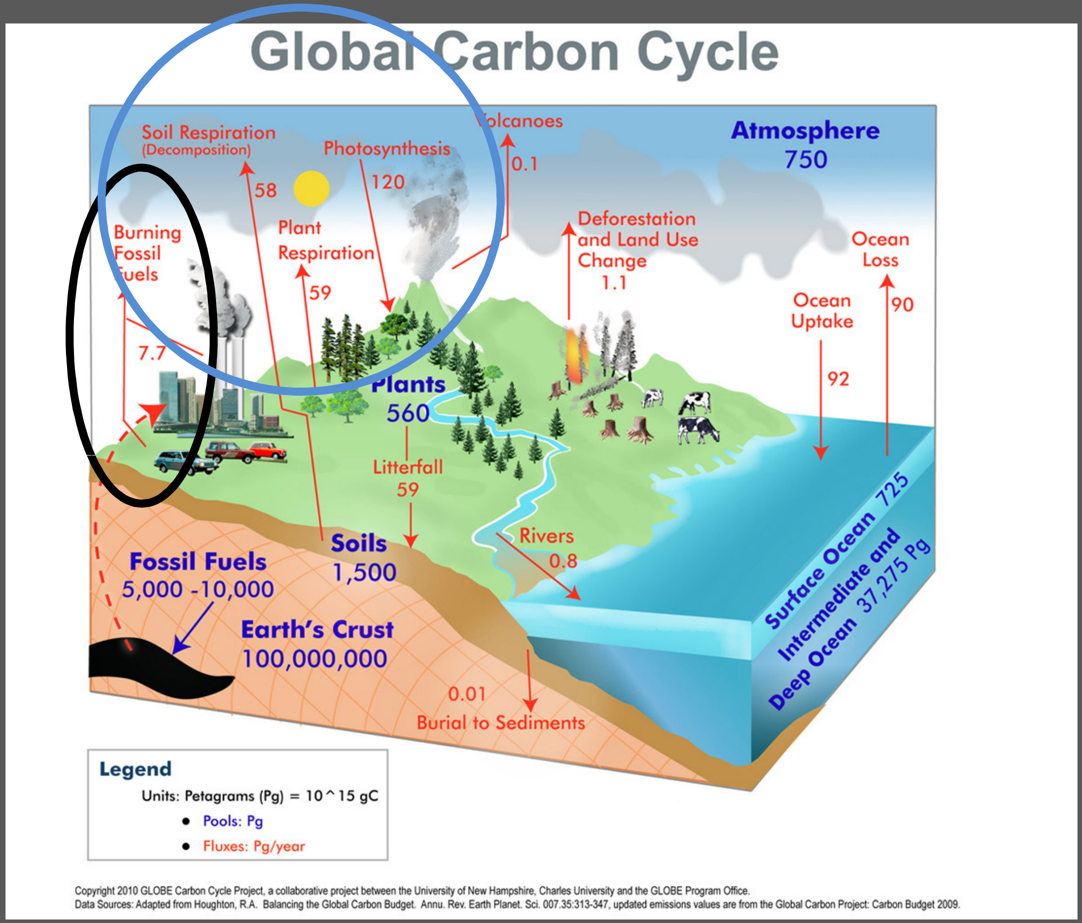
III. So what?

Flux	CO_2	H_2O
Flux IN	Photosynthetic assimilation	Precipitation
Flux OUT	Ecosystem respiration	Evapotranspiration
Net Flux	~ size of the carbon sink	~ amount of water flowing out of the ecosystem

with the tower data, we measure both the net fluxes, and the component fluxes

Vegetative carbon cycling is an important control on atmospheric CO2 concentration

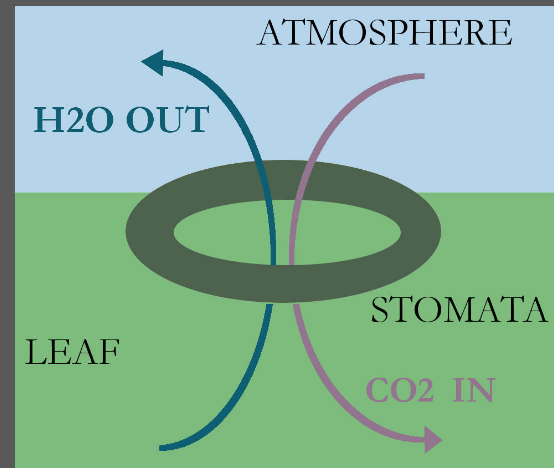
Net land sink = 120 – 58 – 59 = 3 Pg/year



climate changes may affect each photosynthesis and respiration independently

I. WHY

Understanding the controls on ecosystem water fluxes is important



Carbon and water vapor exchange are closely coupled

www.fhm.fs.fed.us

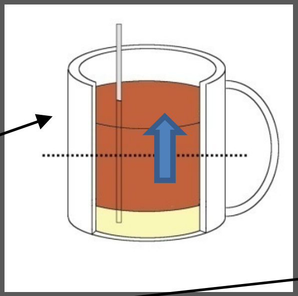
Through transpiraton, forests are first users of precipitation

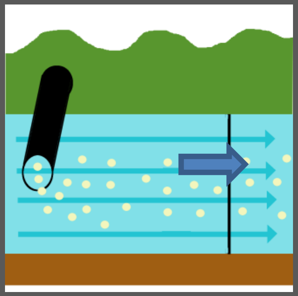
Annual forest transpiration/precipitation ~ 30 – 40 %
Annual forest transpiration/outflow ~ 70 – 135 %

(Oishi et al. 2010, Ford et al. 2007, Schafer et al. 2001)

II. HOW

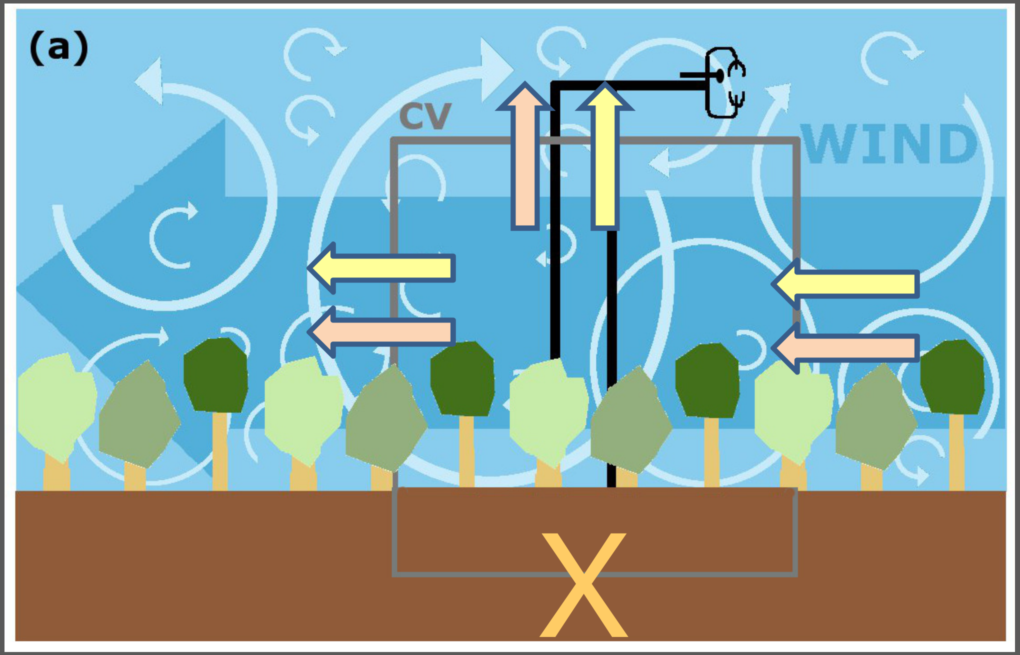
The eddy covariance technique:





Turbulent flux $F_{T,j} = \overline{U_j'c'}$

Advective $F_{A,j} = \int_{x1}^{x2} \overline{U_j} \frac{\overline{\partial c}}{\partial x_j} dx_j$



Assumptions:

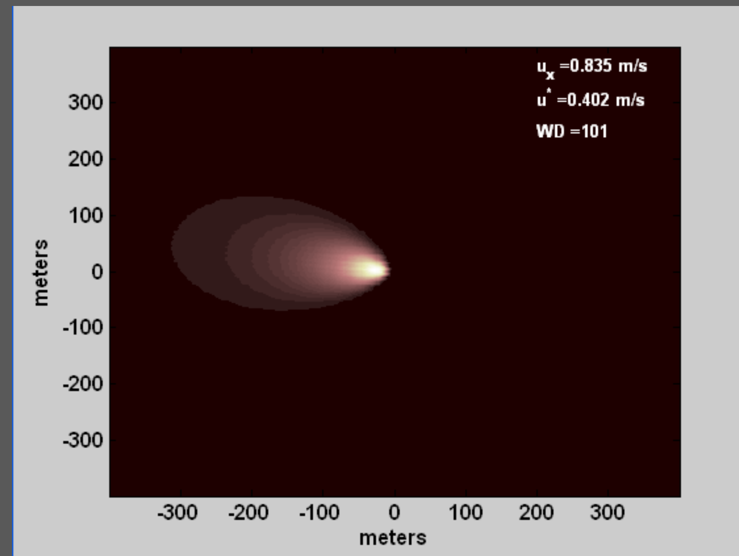
Planar-homogeneous conditions and flow

No subsidence (i.e. no mean vertical wind)

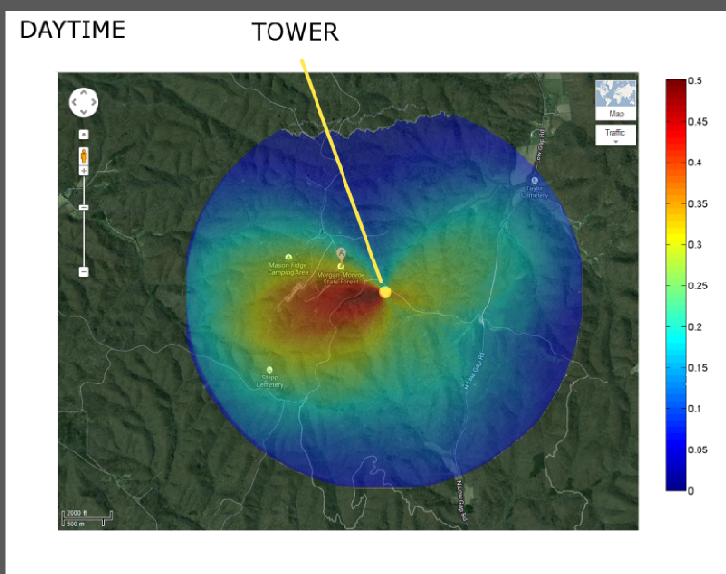
Sufficiently turbulent conditions

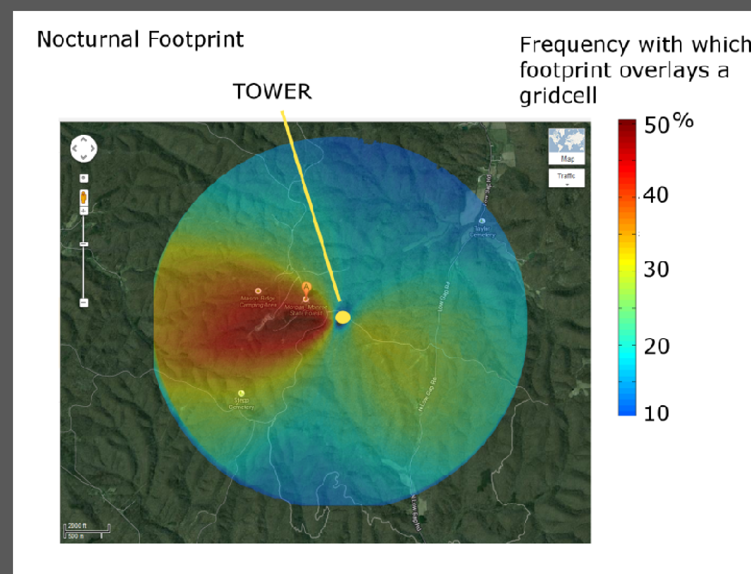
Vertical turbulent flux = $\overline{w'c'}$ = integrated biological sources & sinks

II. HOW



Fluxes are averaged to hourly values, each of which is associated with a unique flux “footprint”

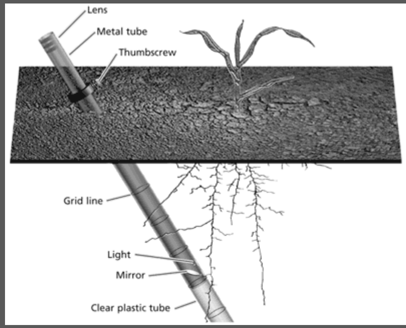




II. HOW

litterfall

Rhizotrons for root growth



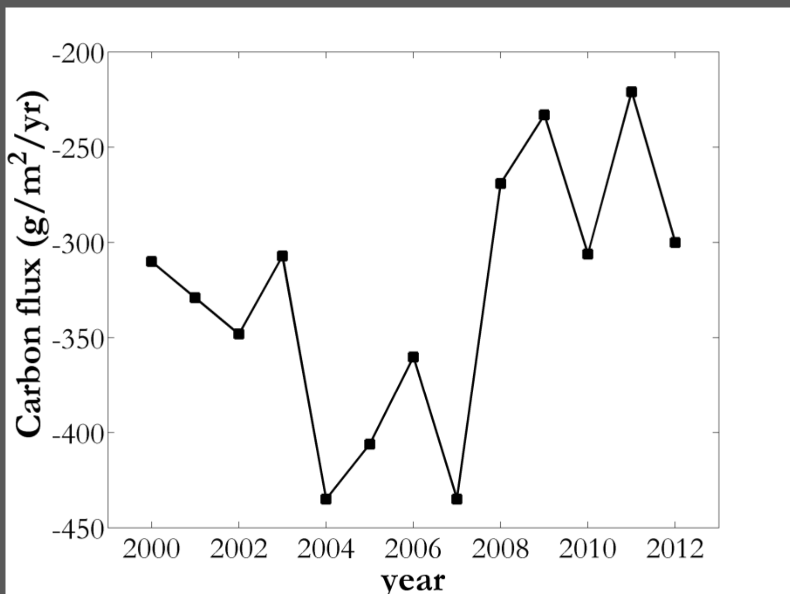
Soil respiration chambers

Leaf-level gas exchange

Sap flux

Dendrometer bands for growth

III. SO, WHAT HAVE WE FOUND?



Carbon flux is -327 g/m2/y on average, and highly variable

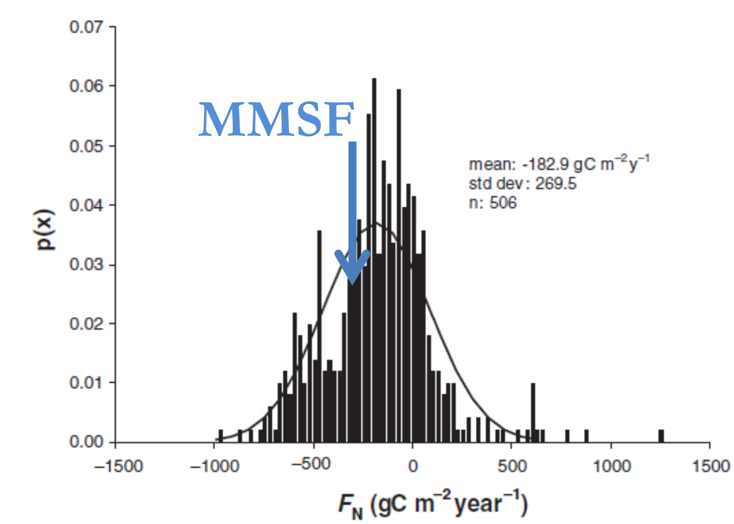


Fig. 4. Probabilistic histogram of published measurements of annual net ecosystem CO_2 exchange. Superimposed is a Gaussian probability distribution. The mean is –183, the median is –169 and the standard deviation is 270 gC m^{-2} year^{-1} from 506 site-years of data.

source: Baldocchi 2008

III. SO, WHAT HAVE WE FOUND?

Data from MMSF has been very important for advancing the theory of eddy covariance measurements

187 citations

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Agricultural and Forest Meteorology 103 (2000) 357–374

AGRICULTURAL AND FOREST METEOROLOGY

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Measurements of CO_2 and energy fluxes over a mixed hardwood forest in the mid-western United States

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Agricultural and Forest Meteorology 126 (2004) 185–201

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44 citations

Heat storage and energy balance fluxes for a temperate deciduous forest

A.J. Oliphant[a,*], C.S.B. Grimmond[b], H.N. Zutter[b], H.P. Schmid[b], H.-B. Su[c], S.L. Scott[b], B. Offerle[b], J.C. Randolph[d], J. Ehman[d]

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[c]*Department of Geography, East Carolina University, USA*
[d]*School of Public and Environmental Affairs, Indiana University, USA*

Global Change Biology (2002) **8**, 575–589

75 citations

An initial intercomparison of micrometeorological and ecological inventory estimates of carbon exchange in a mid-latitude deciduous forest

J. L. EHMAN*, H. P. SCHMID†, C. S. B. GRIMMOND†, J. C. RANDOLPH*, P. J. HANSON‡, C. A. WAYSON* and F. D. CROPLEY†

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III. SO, WHAT HAVE WE FOUND?

Data from MMSF has been used to validate satellite and modeling products

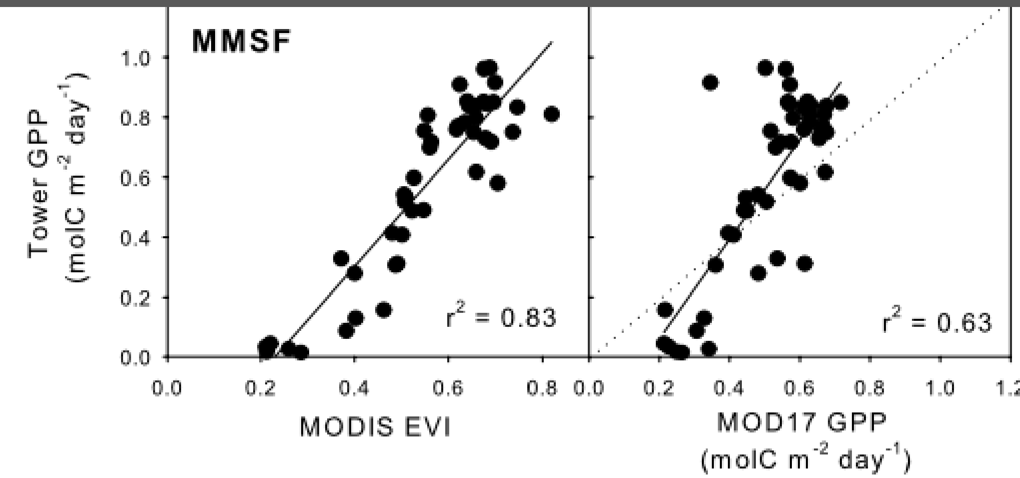
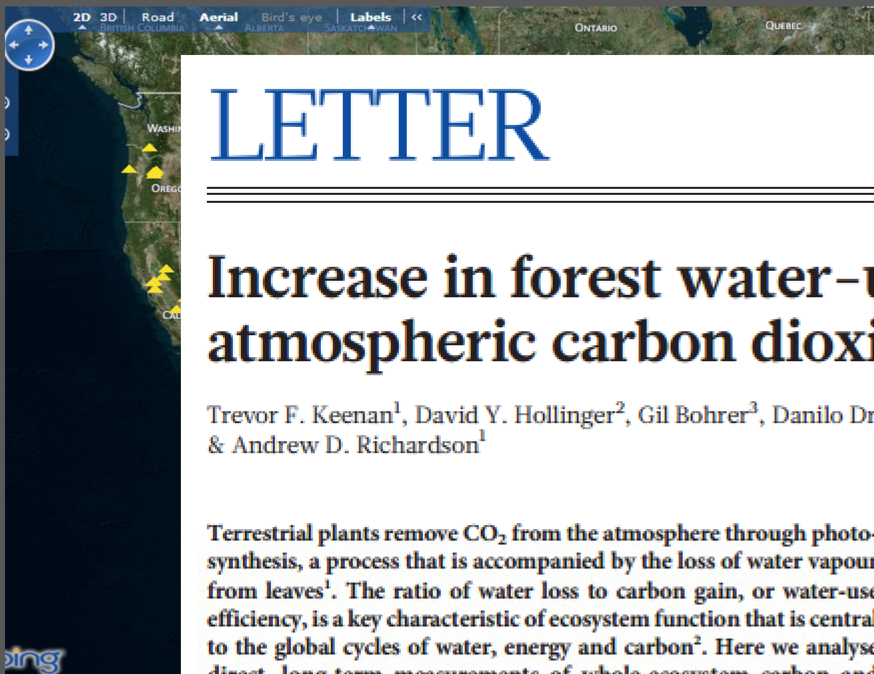


Figure 2. Gross primary production measured at the flux towers (Tower GPP) as a function of the MODIS-enhanced vegetation index (EVI) and the MOD17 GPP for each of the sites with predominantly deciduous vegetation. Data are means for the 3 × 3 km area centered on the tower and include only the active period. All relationships are statistically significant at $p < 0.01$.

Sims et al., 2006

Ameriflux



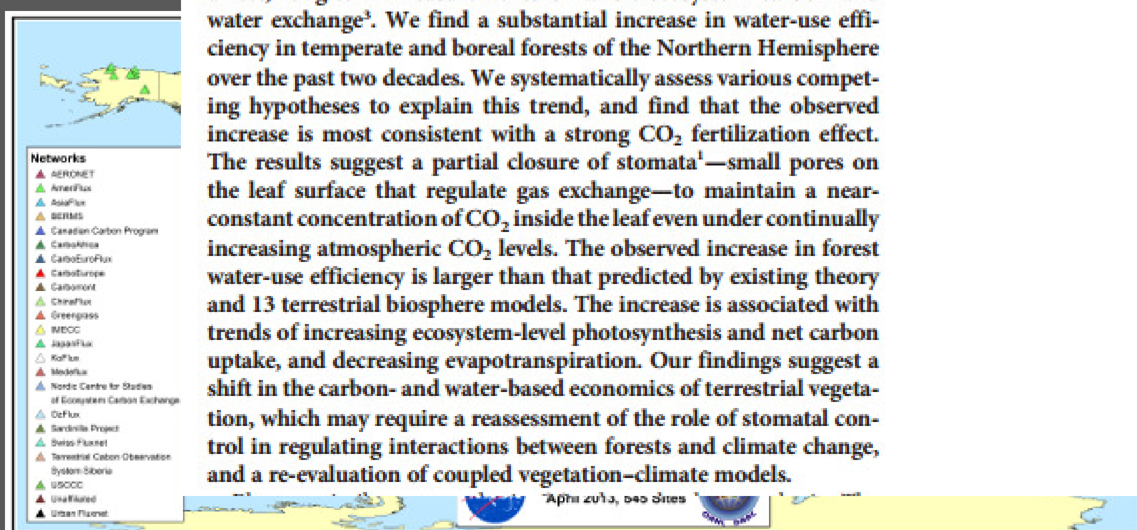
LETTER

doi:10.1038/nature12291

Increase in forest water-use efficiency as atmospheric carbon dioxide concentrations rise

Trevor F. Keenan[1], David Y. Hollinger[2], Gil Bohrer[3], Danilo Dragoni[4], J. William Munger[5], Hans Peter Schmid[6] & Andrew D. Richardson[1]

Terrestrial plants remove CO_2 from the atmosphere through photosynthesis, a process that is accompanied by the loss of water vapour from leaves[1]. The ratio of water loss to carbon gain, or water-use efficiency, is a key characteristic of ecosystem function that is central to the global cycles of water, energy and carbon[2]. Here we analyse direct, long-term measurements of whole-ecosystem carbon and water exchange[3]. We find a substantial increase in water-use efficiency in temperate and boreal forests of the Northern Hemisphere over the past two decades. We systematically assess various competing hypotheses to explain this trend, and find that the observed increase is most consistent with a strong CO_2 fertilization effect. The results suggest a partial closure of stomata[1]—small pores on the leaf surface that regulate gas exchange—to maintain a near-constant concentration of CO_2 inside the leaf even under continually increasing atmospheric CO_2 levels. The observed increase in forest water-use efficiency is larger than that predicted by existing theory and 13 terrestrial biosphere models. The increase is associated with trends of increasing ecosystem-level photosynthesis and net carbon uptake, and decreasing evapotranspiration. Our findings suggest a shift in the carbon- and water-based economics of terrestrial vegetation, which may require a reassessment of the role of stomatal control in regulating interactions between forests and climate change, and a re-evaluation of coupled vegetation–climate models.



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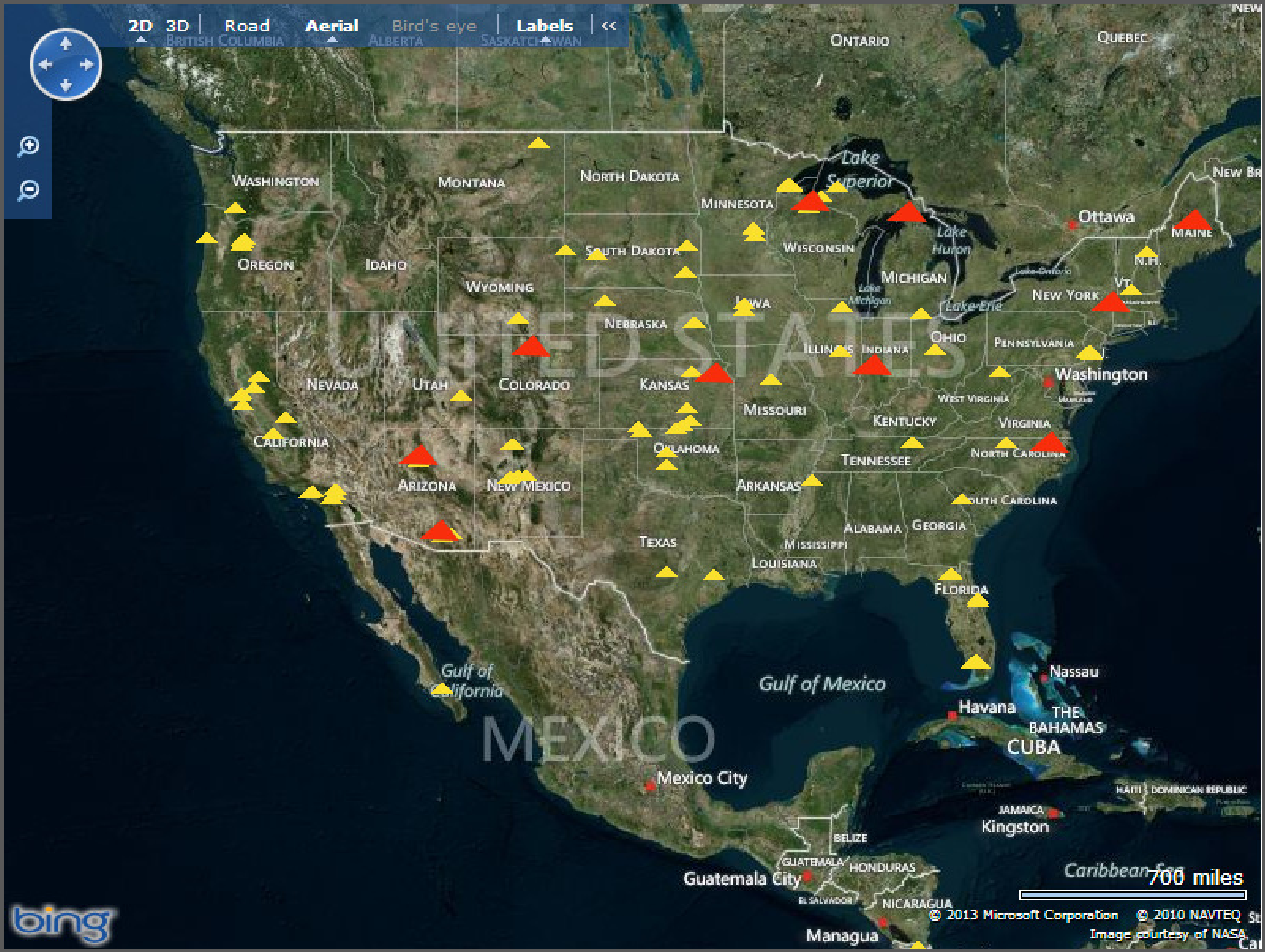
IV. LOOKING FORWARD

Ameriflux



The MMSF tower was recently selected to be a Ameriflux CORE site.

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Faculty: Hans Peter Schmid, Sue Grimmond, Danilo Dragoni, JC Randolph, Rich Phillips, Faiz Rahman, Tom Evans

Post-Docs: Daniel Sims, Craig Wayson, Andrew Oliphant, Hong-Bin Su

Technicians: Tyler Roman, Steve Scott

A large number of current and prior PhD, MS, MPA, BS, and BA students